THE CATHOLIC UNIVERSITY OF EASTERN AFRICA

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MAIN EXAMINATION

SEPTEMBER –DECEMBER 2021

FACULTY OF SCIENCE

DEPARTMENT OF CHEMISTRY

REGULAR PROGRAMME

CHEM 402: CHEMICAL THERMODYNAMICS

Date: DECEMBER 2021	**Duration: 2 Hours**
INSTRUCTIONS: Answer Question ONE and any TWO Questions	

Physical Constants:

R = 8.314 J/K.mol,;
Specific Heat capacity of Iron (C_s) = 0.45 J/g.K;
Specific Heat capacity of Water (C_s) = 4.2 J/g.K;
Atomic mass of Hydrogen = 1g/mol;
Atomic mass of Chlorine = 35.5g/mol;
Standard molar Entropy for Nitrogen gas (S^o_{N2})= 191.6 J/mol.K;
Standard molar entropy for Hydrogen gas (S^o_{H2}) = 130.7 J/mol.K;
Standard molar entropy of ammonia (S^o_{NH3}) = 192.77 J/mol.K;
C_v for Nitrogen = 20.8 J/K.mol
Molar mass of Nitrogen gas = 28 g/mol

Q1. a) Define the following terms as used in chemical thermodynamics:

i. Adiabatic Boundary
ii. Reversible Isothermal Compression
iii. The First Law of Thermodynamics
iv. Entropy

v. Standard Enthalpy of Neutralization **(10 marks)**

b) 55 grams of hydrogen chloride gas undergoes reversible isothermal expansion from 20 to 33 liters at a temperature of 300K.

i. Calculate the work done (w) by the gas **(3 marks)**

ii. Calculate the entropy change (ΔS) for the gas **(2 marks)**

c) Write the equations for the relationship between ΔG and:

i. Equilibrium constant (K)

ii. Cell potential (E) **(4 marks)**

d) Using relevant diagrams, describe the flow of heat

i. In a refrigerator

ii. In a heat engine **(6 marks)**

e) i. Write the expression for the Clausius inequality principle for an irreversible reaction **(2 marks)**

ii. In an industrial process, 31,500kJ of heat is added at 410^{o}C and 19,500kJ is rejected at 20^{o}C. Is the Clausius inequality satisfied? Is it reversible or irreversible? **(3 marks)**

Q2. a) If $\Delta H = \Delta U + P\Delta V$, show that $C_p = C_v + nR$ **(4 marks)**

b) 20grams of an iron piece at 573K is dipped into 1.5 liters of water at 298K. The temperature of the iron piece falls to 423K. Calculate the final temperature of the water **(6 marks)**

c) Describe any three thermodynamic processes **(6 marks)**

d) i. Write the mathematical expression for Boltzmann's entropy **(2 marks)**

ii. Calculate the numbers of microstates possible for a gas if 4 molecules (*x*) can occur in 10 different positions (*n*) **(2 marks)**

Q3. a) Explain why the entropy of a gas is considered greater than that of a solid or liquid **(4 marks)**

b) 60g of nitrogen gas undergoes reversible isothermal expansion from 11litre to 24 liters at a temperature of 300K. It then expands adiabatically to 27 liters with a temperature drop to 215K. It is then isothermally compressed to 16 liters before adiabatically being compressed to the original volume at the starting temperature.

i. Draw the Carnot cycle diagram for the 4 steps **(4 marks)**
ii. Calculate the work done in each step **(4 marks)**
iii. Calculate the total work done and the Carnot efficiency of the cycle **(2 marks)**

c) Explain why:

i. $\Delta U = \pm w$ in an adiabatic process **(3 marks)**
ii. $\Delta U = \pm q$ in an isochoric process **(3 marks)**

Q4. a) Describe the third law of thermodynamics **(3 marks)**

b) The entropy change in solids can be determined using the following equation:

$$\Delta S = n\, C_p \ln \frac{T_2}{T_1}$$

i. Calculate T_2 for 0.5 moles of a solid with a Cp of 30 J/K.mol. if the ΔS is 16.5 and the T_1 is 100K **(3 marks)**
ii. What is the effect of an increase in temperature on entropy change (ΔS) **(3 marks)**

c) Two compartments, A and B are isolated from their surroundings using an adiabatic boundary but are separated from each other using a diathermal boundary. The temperature of compartment A (T_A) is 450K while that of compartment B (T_B) is 105K.

i. Draw the two compartments indicating the boundaries, temperatures and direction of heat flow **(6 marks)**
ii. If upon the flow of heat, compartment A has a ΔU_B of +30J, calculate the total ΔS **(3 marks)**

d) Explain why q and w are path functions not dependent on the state of a system

(2 marks)

Q5. a) Define the following:

i. Standard enthalpy change of formation
ii. Standard enthalpy change of combustion
iii. Standard enthalpy change of solution **(6 marks)**

b) Calculate the ΔS^{o}_{rxn} for the following reaction:

$2NH_{3(g)} \rightarrow N_{2(g)} + 3H_{2(g)}$ **(4 marks)**

c) In a certain reaction, K varies with temperature in the following way:

Experiment	**Temperature (T)**	**Equilibrium constant (K)**
1	105K	1.02
2	200K	1.75
3	310K	2.05
4	409K	2.65

Using the van't Hoff equation, plot a graph of *ln* K vs 1/T to determine whether the reaction is exothermic or endothermic **(6 marks)**

d) Describe the difference between molar heat capacity and specific heat capacity

(4 marks)

END